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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application of Anderson et al. Art Unit 3761
Serial No. 10/623,030
Filed July 18, 2003
Confirmation No. 4469
For ABSORBENT ARTICLE WITH HIGH QUALITY INK JET IMAGE PRODUCED AT LINE SPEED
Examiner Laura C. Hill

January 10, 2007

DECLARATION OF KIMBERLY D. ANDERSON, MICHAEL J. GARVEY, MELISSA C. PUTZER, TIMOTHY PROBST, AND ERIC D. JOHNSON

TO THE COMMISSIONER FOR PATENTS,

SIR:

We, Kimberly D. Anderson, Michael J. Garvey, Mel~~l~~issa C. Putzer, Timothy Probst, and Eric D. Johnson, declare as follows:

1. We are the co-inventors of the subject matter claimed in U.S. Patent Application No. 10/623,030, filed on July 18, 2003.

2. Drop on demand piezoelectric ink jet printing apparatus (e.g., ink jet non-contact printing systems) have been used to apply inks to a variety of substrates. Generally, a drop on demand piezoelectric ink jet printing apparatus discharges small individual droplets of ink onto a substrate in a predetermined pattern. In this type of printing apparatus, the print head does not contact the substrate on which the image is printed. Such apparatus typically incorporate a print head having an array of orifices in a block, and a controller. Each orifice is

designed to emit a single droplet of ink onto the substrate each time its associated print head fires.

3. The quality of an image produced by a drop on demand ink jet printer has long been thought to be a function of the resolution of the image, i.e., a certain area of coverage of the substrate by the ink. See Digital Printing of Textiles, Woodhead Publishing, 2006, section 7.4.1 (a copy of which is attached hereto. The image resolution is typically defined in terms of the surface area of the web covered by a given amount of ink, and more particularly the ink dot density which is commonly given as dots-per-inch (dpi). A greater dpi has thus been associated with a greater resolution, and hence an increased quality ink jet image on the web.

4. Absorbent articles such as diapers and training pants are typically manufactured in a line process in which the various components of the article are assembled at high speeds such as 100 feet per minute and more often about 1,200 feet per minute or more. Prior to the present invention, due in part to print head limitations, graphic images that appear on such articles were applied by ink jet printing in an off-line process in which the graphic was imprinted on a film or non-woven web off-line, at lower speeds and over multiple passes of the web past the print head, and the graphic web was subsequently introduced to the manufacturing line at the higher line speed. The resolution of such images was about 300 dpi to about 600 dpi or even higher.

5. We deemed it advantageous, however, to be able to print graphics onto the moving article in a single pass and at the higher line speeds (e.g., the manufacturing line speed), such as a reduced number of processing steps, increased flexibility in changing graphics during manufacturing and other manufacturing efficiencies.

6. About the time of our invention of the presently claimed subject matter, we experimented with new print head technology operating at higher line speeds. Conventional wisdom dictated that to maintain the image quality of the graphic, the resolution of the graphic image would have to at least stay the same (e.g., 300 to 600 dpi) at higher line speeds, meaning that the print head would have to output more ink as the line speed increased.

7. Accordingly, as the line speed was increased during the experiment, we increased the ink delivery rate to maintain the dpi of the graphic. However, unexpectedly, the graphic produced at these dpi and higher line speed rates was blurred, or smeared.

8. Upon further increasing the line speed, we exceeded the ink delivery rate capabilities of the print head so that the dpi of 300-600 could no longer be maintained (e.g., to see just how high of a line speed the print head could be used with). This resulted in the image resolution dropping substantially below 300 dpi. However, the quality of the image was unexpectedly as good as, or better than, images previously produced at 300-600 dpi and slower line speeds

and certainly better than images produced at 300-600 dpi at the higher line speeds.

9. As a result of our experimentation, we determined that high quality images could be produced on absorbent articles moving at line speeds of 30.5 meters per minute (100 feet per minute) or greater using ink jet printing with a resolution of about 100 dots per inch (dpi). Such a result was unexpected in view of the previously common belief that increasing line speeds required a more rapid ink delivery rate (relative to the line speed) to the web, not a lower rate.

10. U.S. Patent No. 6,096,412 (McFarland et al.), which is cited in the final Office action dated August 15, 2006, specifically teaches that "[t]he higher color density of the ink, the greater the intensity or strength of the color." See col. 19, lines 3-5. This reflects the conventional thinking of those skilled in the art prior to the present invention that the <u>more ink</u> that is applied to the article the greater the quality of the image. The present invention, however, allows <u>less ink</u> to be used while obtaining high quality graphics at higher line speeds. Thus, producing an article with a more vibrant, brighter image while using less ink is indeed an unexpected result in view of the teachings of McFarland et al.

11. Each of us declare that all statements made herein are true; and further that these statements were made with the knowledge that willfully making false statements is punishable by fine, imprisonment, or both, under 18 U.S.C.

§1001 and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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7.3 Market needs for digital textile printing

There are various market needs for digital textile printing that differ from WFPs for graphics, compared to conventional screen textile printing:

- Productivity: 20–30 m^2/h print speed for practical use
- High resolution: enabling printing of fine tie patterns
- Support of various fabric types: stretching/shrinking, thin, raising fabric, etc.
- Color reproduction: equal or higher color gamut to screen textile printing; high color reproduction when reprinting or between different models
- Strike-through: color permeability to rear surface (especially for scarves)
- High fastness: equal fastness to screen textile printing
- Low running costs: slightly higher printing costs than manual textile printing.

The importance and achievement level of these needs differ depending on the intended purpose of the digital textile printing. For small lot production, productivity and running costs are especially important because of printing end products. For color correction printing, color reproduction and high resolution are important. Before now, many users who introduced the Tx series had used several printers for small lot production. Therefore, the highest market need is demand for productivity and running costs.

7.4 Technical issues and solutions

7.4.1 High resolution images

The quality of digitally printed images is determined by printer resolution, variable dot size, and fabric feed accuracy of digital textile printers, and those factors are now discussed.

Resolution

Printers with finer resolution produce higher-quality output. Conventional screen printers typically use 100 to 300 mesh screens, resolution of which is comparable to 254–770 dpi (100 μm down to 33 μm) for the resolution of digital images. For textile printers, 720 dpi is a practical and necessary plotting resolution. To print actual images with resolution equivalent to that of paper ink-jet printers, it is important to inject the proper amount of ink that gives the right dot length on the textile appropriate to the resolution from the nozzle.

The Tx series adopts a 720 dpi plotting resolution. Realizing 80–100 μm print dot length by 5–25 pl (1 pl = 10^{-12} liter) ink drop size, high-resolution printing is available. The nozzle hole pitch of the ink-jet head incorporated in the Tx series is 180 dpi (141 μm). However, it is capable of performing real 720-dpi resolution (35 μm) printing by scanning four times separately between nozzles. Also, for enhancing image quality, it is possible to print a scanning dot line

every dot using two types of nozzle. In this case, 720 × 720 dpi meshes will be coated by scanning eight times. In the same way, a printing mode using 16 times scanning is available. Printing using multiple scanning is time-consuming. So it is necessary to use the appropriate mode depending on the desired print quality.

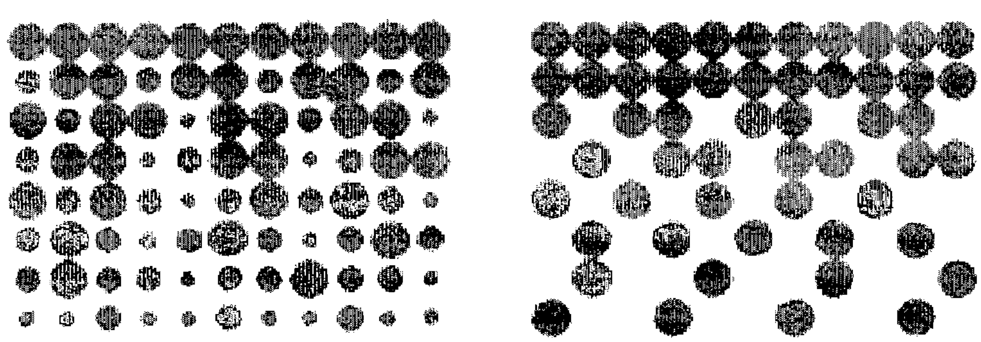
Variable dot size

Popular methods for color tone control are digital dithering, pseudo halftone reproduction using an error diffusion method, and combination with light colors. In gradation of dark colors only, graininess is often apparent in the highlight area where basic dots are large and dark. Use of smaller dots with those methods is effective in reducing graininess and preventing a tone-jump phenomenon. Tx2 and Tx3 printers are capable of manipulating dots in three sizes as shown in Fig. 7.6. These dots in different sizes allow smooth tone gradation with less graininess.

Fabric feed accuracy (banding prevention)

When feed fluctuations for every head scan occur, a striped pattern in the scanning direction (banding) is seen on the resulting print and leads to poor image quality. Banding occurs chiefly because of faulty fabric feed and irregularities in the fabrics themselves. Its causes are as follows:

- Existence or nonexistence of slippage at fabric clamping mechanism part (printer)
- Tension uniformity of fabric (printer)
- Stretch fabric or not (fabric, material)
- Fabric wet expansion/shrinkage by ink (fabric, material)
- Slippery surface of fabric (fabric, material)



(a) (b)

7.6 Tone gradation by variable-sized dots: (a) with variable dot sizes; (b) with a single dot size.

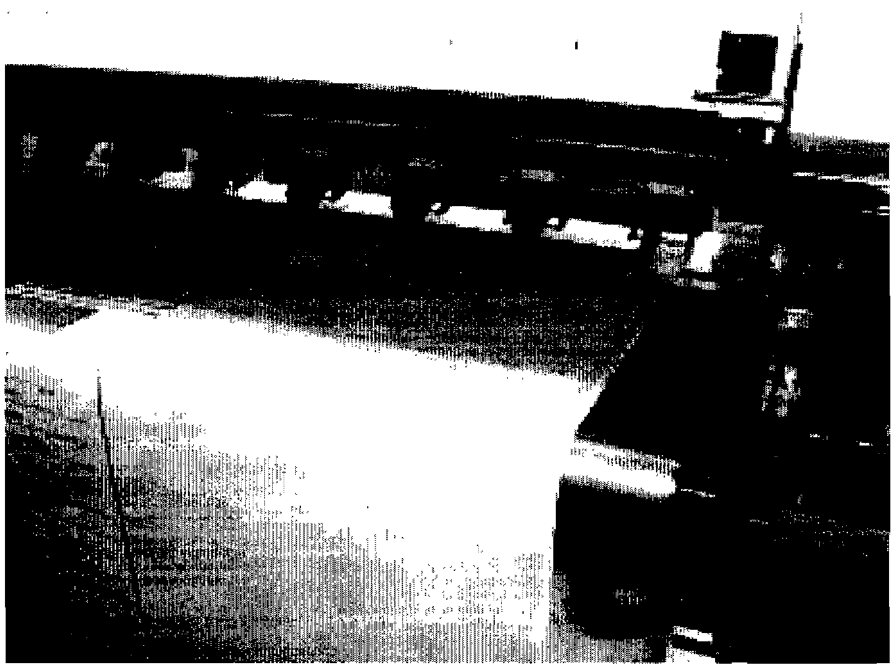
- Concavity and convexity of fabric (embossment, crape) (fabric, material)
- Uniformity of edge of roll fabric (in shape) (fabric, pre-treatment)
- Meandered or curved fabric (fan-like, deformation to s-shape) (fabric, pre-treatment).

The feeder must be equipped with a mechanism that prevents a fed fabric from slipping, and fabric can withdraw easily from it to prevent fabric from imperfection. As the anti-slip mechanism, the Tx2-1600 (Fig. 7.7) and Tx3-1600 (Fig. 7.8) have knurled rollers and a feed system using an adhesive belt (table adhesive method), respectively. The knurled rollers of Tx2 have fine projections on the stainless-steel surface and have strong friction in the thrust direction when winding fabric. If the height of toothing is too great, the amount of toothing to be pierced into the fabric will increase and lead to imperfection in the fabric. Also, fabric cannot be easily withdrawn.

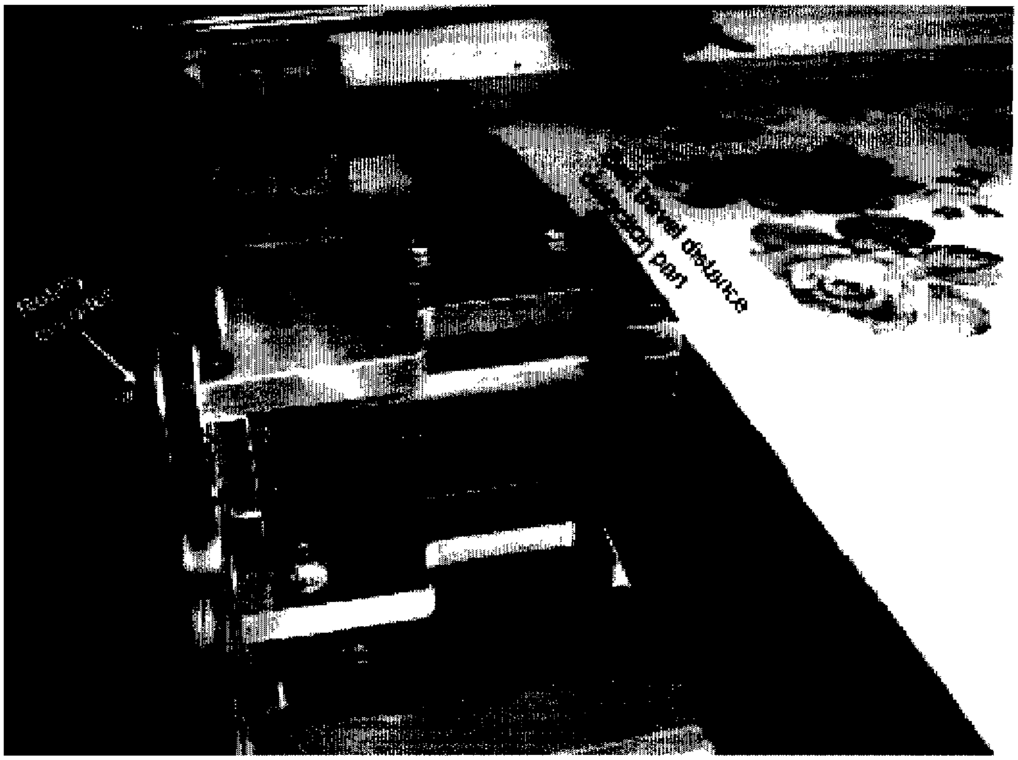
Feeding is performed under fixed tension, pulling the entire fabric by the roller with special surface treatment at the point immediately after printing (Fig. 7.9). Applying clingy paste to the wide endless belt surface, an adhesive belt feeds fabric by sticking it to the belt. Because the entire fabric sticks to the belt, stretch material such as knit can be fed and textiles are prevented from wet expansion/shrinkage by ink. As the adhesive power of paste will deteriorate with use, it is necessary to put paste on the belt periodically. Also, varying thickness

7.7 Tx2 feeding roller.

7.8 Tx3 feeding belt.



7.9 Tx2 fabric tension mechanism.

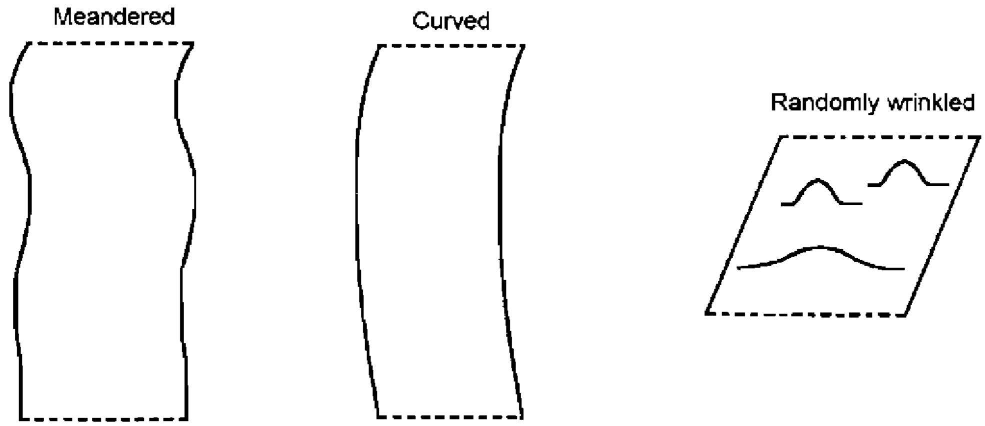


7.10 Tx3 detecting the travel distance of the belt.

of the feeding belt and non-uniform paste lead to accidental errors in fabric feed accuracy. In order to correct feed fluctuations, movement of the belt is controlled by detecting its travel distance at the final stage by a rotary encoder with a feedback system to the belt driver motor (Fig. 7.10).

To reduce variations of the tension applied to the fabric, the Tx2-1600 has a torque limiter and a conditioning roller mechanism followed by the drive section; the Tx3-1600 has parallel tensioning bars. Generally, when feed accuracy has $\pm 20\,\mu m$ or more accidental error, visible banding tends to occur. As mentioned above, fabric characteristics such as expansion/shrinkage, wet expansion/shrinkage by ink, slippery surface, concavity and convexity also affect banding.

Pre-treatment of fabric consists of impregnation by an agent mainly consisting of paste and then drying. This pre-treatment can prevent bleeding of dye inks and improve feed performance. (Section 7.4.3 explains the details of prevention of bleeding.) For fabrics woven with a hard twist and large expansion/shrinkage, pre-treatment paste coating should be increased to improve feed performance. Adjustment of the composition of the agent, width of the tenter, speed and strength of take-up by the fabric all affect the result. If the make-up of the agent is not suitable, fabric may be starched or stressed, causing skewed feeding, meandering, and non-uniform pitch. These cause banding. Figure 7.11 shows typical examples of results of pre-treatment. Skewing of the fabric causes banding, fabric slip upon feeding, and wrinkles, eventually leading



7.11 Skewing caused in the pre-treatment.

to the head nozzle dragging on the print fabric surface and to fabric jamming in the printer.

7.4.2 Color reproduction

Figure 7.12 compares the color gamuts of reactive dyes, acid dyes, disperse dyes, and water-based pigment inks. The figure suggests that the color gamut of dye inks compares favorably with that of pigment ink.

7.4.3 Prevention of bleeding

Conventional screen printing and ink-jet printing use different pastes for print inks. To prevent ink bleed, screen printing uses a volume of pastes that makes inks much more viscous than those for ink-jet printing for dye. We call the mixture of textile dye ink and pastes 'printing pastes'. Hand screen printing, automatic flat-bed screen printing, and rotary screen printing use pastes with lower viscosity in that order. Generally, screen printing uses pastes with viscosity of some hundreds to tens of thousands of mPa·s. Ink-jet printing adopts pastes with much lower viscosity, from a few to over 10 mPa·s. It requires light pastes for spraying ink droplets of a few to several tens of picoliters in size at a high jet frequency of approximately 10 kHz from the printer head nozzles. Ink droplets with low viscosity pastes would produce ink bleed on a fabric. Therefore, coating the target fabric with a pre-treatment agent, the main element of which is a paste, is necessary.

Ink bleed and strike-through on the printed fabric occur due to a capillary phenomenon. The ink penetration length through the capillary is calculated with the Lucas–Washburn equation, which expresses the relation between the penetration length L and the viscosity δ as follows:

$$L \propto \delta^{-1/2} \tag{7.1}$$